# SHEAR STRENGTH STUDIES OF KUANTAN BAUXITE

SYAHMI SYAFIQ BIN SALAHUDDIN

B. ENG (HONS.) CIVIL ENGINEERING

UNIVERSITI MALAYSIA PAHANG

## STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

_____

(Student's Signature)

Full Name : SYAHMI SYAFIQ BIN SALAHUDDIN

ID Number : AA 15151

Date : 31 MAY 2019

# SHEAR STRENGTH STUDIES OF KUANTAN BAUXITE

SYAHMI SYAFIQ BIN SALAHUDDIN

Thesis submitted in partial fulfillment of the requirements
for the award of the
B. Eng (Hons.) Civil Engineering

Faculty of Civil Engineering & Earth Resources
UNIVERSITI MALAYSIA PAHANG

MAY 2019

**ACKNOWLEDGEMENT**

In the name of Allah S.W.T, most gracious and most merciful, with His permission, *Alhamdulillah* the report has been completed. His companions and to those on the path as what he preached upon, may Allah Almighty keep us His Blessing and tenders.

I wish to express my gratitude to my supervisor, Prof. Madya Dr. Haryati Awang, I would like to express her my deepest appreciation for providing invaluable help, enthusiastic guidance, patience and support in my quest to complete this proposal. May the precious knowledge that I gained from her will be rewarded by Allah S.W.T.

I would like to thank the Faculty of Civil Engineering and Earth Resources (CIVER) for providing all the necessary equipment and materials to pursue this research. Special thanks are also given to my beloved parent for their non–stopping support, encouragement, motivation, and pray for me to complete my report. Last but not least, also million thanks to my colleagues who directly and indirectly had given moral support and constant encouragement along the completion of this study, their help and support will always be remembered; may Allah S.W.T will bless you all, Insha-Allah.

May Allah S.W.T the Almighty accept this humble contribution to knowledge, Amin.

## ABSTRACT

Soil investigation is an important step in Civil Engineering, especially in construction of buildings. One of the soil investigations is determining the shear strength of the soil, where shear strength of soil is important in determining the condition of the soil. It is also important in determining the designing of the foundation structure for building. For this study, Unconsolidated Undrained (UU) Triaxial Test was conducted to measure the displacement and the strength of soil. This study also examines the suitability of the soil as foundation for development purposed. From the test, soil deviator stress, number of stress applied and soil type are considered. From the results obtained from testing that were carried out, parameter of the shear strength, cohesion ("c") and friction angle ("φ") can be determined from Mohr Circle. From the parameter obtained, the value of the bearing capacity can be calculated and used for foundation construction.

# ABSTRAK

Penyiasatan tanah merupakan langkah penting dalam Kejuruteraan Awam, terutama dalam pembinaan bangunan. Salah satu penyiasatan tanah ialah menentukan kekuatan ricih tanah, di mana kekuatan ricih tanah adalah penting dalam menentukan keadaan tanah. Ia juga penting dalam menentukan reka bentuk struktur asas untuk bangunan. Untuk kajian ini, Ujian Tiga Paksi Tidak Terkonsolidasi Tidak Tersalir (UU) telah dijalankan untuk mengukur anjakan dan kekuatan tanah. Kajian ini juga mengkaji kesesuaian tanah sebagai asas untuk tujuan pembangunan. Dari ujian, tekanan penyimpangan tanah, bilangan tekanan yang dikenakan dan jenis tanah dipertimbangkan. Dari hasil yang diperoleh daripada ujian yang dijalankan, parameter kekuatan ricih, perpaduan ("c") dan sudut geseran ("φ") boleh ditentukan dari Bulatan Mohr. Daripada parameter yang diperolehi, nilai kapasiti galas dapat dikira dan digunakan untuk pembinaan asas.

## TABLE OF CONTENT

## LIST OF TABLES

## LIST OF FIGURES

## LIST OF SYMBOLS

| | |
|---|---|
| $M_S$ | Moisture Loss |
| $M_{SL}$ | Mass of Wet Soil and Container |
| $M_{DSL}$ | Mass of Dry Soil and Container |
| $M_D$ | Mass of Dry Soil |
| $M_{DL}$ | Mass of Container |
| w | Water/Moisture Content |
| ε | Strain |
| $L_0$ | Original Specimen Length |
| ΔL | Deformation of Soil |
| $A_0$ | Cross Sectional Area of Sample |
| d | Diameter of Sample |
| *A'* | Corrected Area |
| $S_C$ | Specimen Stress |
| P | Load Applied |
| $q_u$ | Ultimate Load |
| $\sigma_3$ | Confining Stress |
| $(\sigma_1 - \sigma_3)$ | Peak Different Stress |
| c | Cohesion |
| φ | Friction Angle |

## LIST OF EQUATIONS

# CHAPTER 1

# INTRODUCTION

## 1.1 Background of Study

Bauxite is commonly used ore for the production of aluminium. It is a type of rock, usually red in colour, formed from reddish clay soil called laterite soil. Most of the bauxite can be found in tropic region in between 30 degree north and 30 degree south from equator (Gore, 2015). Bauxite is a primary source of aluminium, where 75% of the aluminium worldwide was extracted from bauxite ore. Bauxite comprising chiefly of hydrated aluminium oxides or gibbsite ($Al(OH)_3$), boehmite ( $\gamma$-AlO (OH)) and diaspore (AlO (OH)), including some impurities in form of silica, clay, silt and iron oxides. Mineralogically, bauxite may be classified based on its predominant alumina minerals into 5 types such as pure gibbsitic bauxite, gibbsitic bauxite containing quartz, mixed gibbsitic-boehmite bauxite, boehmitic bauxite, and diasporic bauxite.

Most of the bauxite that used in world was exported from mineral-rich countries such as Australia, Brazil, China, and India. In 2015, world production of bauxite was higher than previous year where mine productions of 299 Mt total was reported from 30 countries. The leading producers of bauxite were, in decreasing order of tonnage mined, Australia, China, Brazil, Malaysia, India, Guinea, and Jamaica. These countries accounted for 91% of total world production; Australia and China together accounted for 49% of the world's production. In 2014, Malaysia accounted for only 1% of total world production of bauxite, but it increased production in 2015 by more than 850% (31.3 Mt) and was the fourth leading producer (12%) (United States Geological Survey,

2016). Table 1.1 shows the world production of bauxite by country with its value for year 2015.

Table 1.1 World productions of bauxite by country and its value for year 2015.

BAUXITE: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Thousand metric tons)

| Country | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|
| Australia | 69,976 | 76,282 | 81,109 | 78,633 | 80,910 |
| Bosnia and Herzegovina | 686 r | 800 | 657 r | 605 r | 787 |
| Brazil | 33,625 | 34,988 r | 33,896 r | 36,308 r | 37,057 |
| China e | 45,000 | 47,000 | 50,400 r | 59,200 r | 65,000 |
| Dominican Republic | -- | 11 | 770 | 1,446 r | 1,724 |
| Fiji | 50 | 300 | 460 | 376 | 250 e |
| Ghana | 236 r | 710 r | 817 r | 906 r | 1,026 |
| Greece | 2,324 | 1,816 | 1,844 r | 1,873 r | 1,832 |
| Guinea[4] | 15,696 | 16,041 | 16,887 r | 17,258 r | 16,303 |
| Guyana[4] | 1,818 | 2,210 | 1,649 | 1,602 | 1,500 e |
| Hungary | 155 r | 144 r | 94 r | 14 r | 8 |
| India | 13,000 r | 15,300 r | 20,420 r | 22,580 r | 27,064 |
| Indonesia | 40,644 | 31,443 | 57,024 r | 2,555 | 202 |
| Iran | 847 r | 892 r | 789 r | 931 r | 900 e |
| Jamaica[4, 5] | 10,189 | 9,339 | 9,435 | 9,677 | 9,629 |
| Kazakhstan | 5,495 | 5,170 | 5,192 | 4,516 r | 4,683 |
| Malaysia | 183 r | 122 | 209 | 3,665 r | 35,000 e |
| Mexico[6] | 14 | 96 | -- | -- | -- e |
| Montenegro | 159 r | -- | 61 r | 155 r | 50 |
| Mozambique | 10 | 8 | 7 r | 3 r | 5 e |
| Pakistan e | 9 r | 30 [3] | 27 r, [3] | 30 | 31 |
| Russia | 5,943 | 5,700 r | 6,028 r | 6,293 r | 5,900 |
| Saudi Arabia[6] | 206 r | 760 r | 1,044 r | 1,965 r | 2,397 |
| Sierra Leone | 1,300 | 776 | 616 | 1,161 | 1,334 |
| Solomon Islands | -- | -- | -- | -- | 270 |
| Suriname | 3,236 | 2,873 r | 2,706 r | 2,708 r | 1,600 |
| Tanzania | 38 | 59 r | 33 r | 26 r | 26 e |
| Turkey | 1,025 | 1,521 r | 796 r | 1,091 r | 1,100 e |
| United States | W | W | W | W | W |
| Venezuela | 2,455 | 2,286 | 2,341 r | 2,346 r | 992 |
| Vietnam e | 100 | 100 | 482 [3] | 1,090 [3] | 1,150 |
| Total | 254,000 | 257,000 r | 296,000 r | 259,000 r | 299,000 e |

eEstimated. rRevised. W Withheld to avoid disclosing company proprietary data; not included in total. -- Zero.

[1]World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes data available through May 12, 2017.

[3]Reported figure.

[4]Dry bauxite equivalent of crude ore.

[5]Bauxite processed for conversion to alumina in Jamaica plus kiln-dried ore prepared for export.

[6]Includes low-grade bauxite consumed for nonmetallurgical uses.

In Malaysia, the exploitation of bauxite mining starts to rise after government of Indonesia has ban the exportation of bauxite and other unprocessed mineral ores in 2014 . The export ban was part of the 2009 Mining Law and was intended by government of Indonesia to increase the economic development in the country through investment in mineral processing facilities. Several foreign companies have invested in alumina refineries in Indonesia (Yee, 2014). The export ban causing sudden increase demand of mineral resources by manufactures country, especially from China. To fill the demand, Malaysia has increase the production of bauxite ore in 2014 by approximately 3,445 thousand metric tons and reach highest peak in 2015 by approximately 35,000 thousand metric tons.

The sudden outburst of mining gives negative impact on surrounding environment around the mining site. There are much pollution caused by bauxite industries such as air pollution, water pollution and sound pollution. The processing of bauxite caused red dust to cover all the nearby roads, vehicles, and may cause hazard to resident and other living organism that stays nearby the plant. The river nearby the mining site becomes full of red mud, causing the river become cloudy and totally useless for cleaning purposes. These problems caused Malaysia government to declare a temporary ban on mining aluminium at the end of 2015.

## 1.2 Problem Statement

As Kuantan is a city of state of Pahang, it experiences rapid development, causing many engineering structures need to be built. Engineering structures such as manufacturing factories need to be built to increase the manufacturing activities, causing increasing of demands for residential area for workers which lead to insufficient land to be used for development.

To overcome the problem, new land area must be proposed to fulfil the needs. Unusable land such as abandoned mining site around Kuantan can be one of proposed land that can be used for development.

Before the construction begins, the soil must be verified its integrity as foundation for the structure. In order to verify the integrity of the soil, a series of test

# REFERENCES


Akademi Sains Malaysia. (2017). *Sustainable Mining: Case Study for Bauxite Mining in Pahang*.

ASTM International. (2010). ASTM D2216-10 - Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass. *ASTM International*. https://doi.org/10.1520/D2216-10

ASTM International. (2015). ASTM D2850-15 Standard Test Method for Unconsolidated-Undrained Triaxial Compression Test on Cohesive Soils. *ASTM International*. https://doi.org/10.1520/D2850-15.2

Authier-Martin, M., Forté, G., Ostap, S., & See, J. (2001). The mineralogy of bauxite for producing smelter-grade alumina. *Jom*, *53*(12), 36–40. https://doi.org/10.1007/s11837-001-0011-1

British Standard Institution. (1990). British Standard Methods of Test for Soils for Civil Engineering Purposes BS1377-2. *British Standard*.

BS 5930:1999. (1999). Code of practice for site investigations. *British Standard*. https://doi.org/10.1016/0148-9062(81)90248-5

Bumij, R. K. (2015). Compaction Characteristics of Red Mud and Pond Ash Mix as Filling and Embankment Material.

Deelwal, K. (2014). Evaluation of characteristic properties of red mud for possible use as a geotechnical material in civil construction. *International Journal of Advances in Engineering & Technology.*, *7*, 1053–1059.

Gore, M. S. (2015). Geotechnical Characterization of Bauxite Residue ( Red Mud ), (August 2015), 287. https://doi.org/10.13140/RG.2.1.2893.7369

Hajdarwish, A., Shakoor, A., & Wells, N. A. (2013). Investigating statistical relationships among clay mineralogy , index engineering properties , and shear strength parameters of mudrocks. *Engineering Geology*, *159*, 45–58.

https://doi.org/10.1016/j.enggeo.2013.03.016

Hasan, M., Ahmad Nor Azmi, A. A. F., Tam, W. L., Phang, B. Y., & Azizul Moqsud, M. (2018). Basic and Morphological Properties of Bukit Goh Bauxite. In *IOP Conference Series: Materials Science and Engineering* (Vol. 318). https://doi.org/10.1088/1757-899X/318/1/012025

International Aluminium Institute. (2014). Bauxite Residue Management : Best Practice, (August). Retrieved from https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=2ahUKEwiX4Lmry TeAhVEWX0KHU4QDtkQFjAAegQICBAC&url=http%3A%2F%2Fwww.world-aluminium.org%2Fmedia%2Ffiler_public%2F2015%2F10%2F15%2Fbauxite_residue_management_-_best_practice_english_oct15ed

Janulikova, M. (2015). The New Options to Reduce Shear Stress into Foundation Structure. *Procedia Engineering*, *114*, 514–521. https://doi.org/10.1016/j.proeng.2015.08.100

Kola, N., & Kumardas, S. (2013). Lateral Earth Pressure Due To Red Mud Using Numerical. In *Proceedings of Indian Geotechnical Conference*.

Newson, T., Dyer, T., Adam, C., & Sharp, S. (2006). Effect of Structure on the Geotechnical Properties of Bauxite Residue. *Journal of Geotechnical and Geoenvironmental Engineering*, *132*(2), 143–151. https://doi.org/10.1061/(ASCE)1090-0241(2006)132:2(143)

Nikraz, H. R., Bodley, A. J., Cooling, D. J., Kong, P. Y. L., & Soomro, M. (2007). Comparison of Physical Properties between Treated and Untreated Bauxite Residue Mud, (January), 2–9. https://doi.org/10.1061/ASCE0899-15612007 19:12

Pajović, M. (2009). Archive of SID Genesis and genetic types of karst bauxites, *1*, 44–56.

Schulte, R., & Foley, N. (2014). Compilation of Gallium Resource Data for Bauxite Deposits, 21. Retrieved from https://pubs.usgs.gov/of/2013/1272/pdf/ofr2013-1272.pdf

Shahin, M. A., Mardesic, T., & Nikraz, H. R. (2011). Geotechnical characteristics of bauxite residue sand mixed with crumbed rubber from recycled car tires. *Journal of GeoEngineering*, *6*, 63–72. https://doi.org/10.6310/jog.2011.6(1).6

Terzaghi, K. (2007). *Theoretical Soil Mechanics*. *Theoretical Soil Mechanics*.

https://doi.org/10.1002/9780470172766

United States Geological Survey. (2016). 2015 Minerals Yearbook: Tantalum. *U.S. Geolocial Survey Minerals Yearbook*, (January). Retrieved from https://minerals.usgs.gov/minerals/pubs/commodity/aluminum/myb1-2015-alumi.pdf

Vesic, A. S. (2003). Analysis of ultimate loads of shallow foundations. *International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abstracts*. https://doi.org/10.1016/0148-9062(74)90598-1

Wang, P., & Liu, D. Y. (2012). Physical and Chemical Properties of Sintering Red Mud and Bayer Red Mud and the Implications for Beneficial Utilization. *Materials*, *5*(10), 1800–1810. https://doi.org/10.3390/ma5101800

Yoshida, Yoshitaka; Kuwano, Jiro; Kuwano, R. (1991). Effects of Saturation on Shear Strength of Soils, *31*.